NASA Dryden Status

Aerospace Control & Guidance Sub-committee
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Abstract

NASA Dryden has been engaging in some exciting work that will enable lighter weight and more fuel efficient vehicles through advanced control and dynamics technologies. The main areas of emphasis are "Enabling Light-weight Flexible Structures", real time control surface optimization for fuel efficiency and autonomous formation flight. This presentation provides a desciption of the current and upcoming work in these areas. Additionally, status is for the Dreamchaser pilot training activity and autonomous aerial refueling of the Global Hawk UAS's.

Enabling Light Weight Flexible Structures

Develop algorithms, sensors and architectures to enable static shape and dynamic control of light weight flexible aerostructures

- **Multi-Utility Technology Testbed (MUTT)**
- **Advanced Sensors for controlling flexible structures**
- **Modeling, Simulation and Control**

X-56A Multi-Utility Technology Testbed (MUTT)

- **Schedule**
  - **1st vehicle delivery to Lockheed end of April 2012**
  - **Moved to Dryden (EAFB) in June of 2012**
  - **AFRL flights begin in late June**

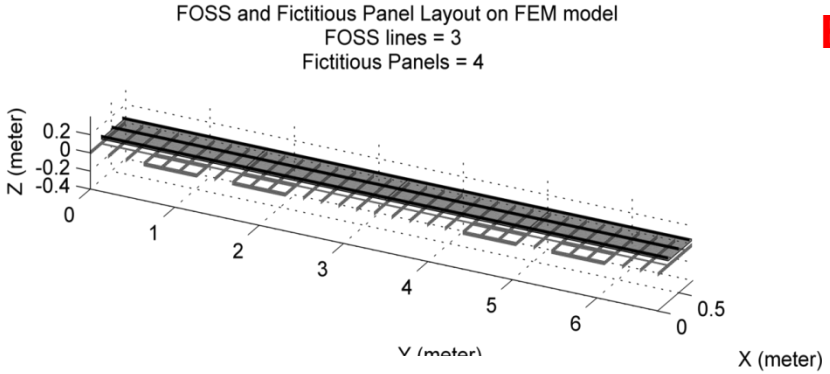
- **X-56A - designed by Lockheed Martin Corp. under AFRL contract and is currently being manufactured and assembled at GFMI Aerospace and Defense in Fountain Valley, CA**

X-56A Multi-Utility Technology Testbed (MUTT)

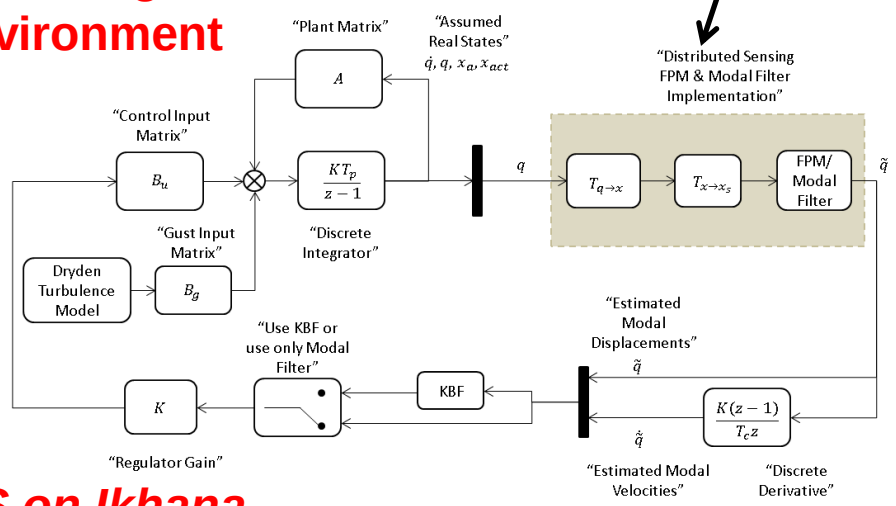
- **NASA research interests**
  - **Develop robustness criteria for active structural control**
  - **Integrate emerging sensor technology (i.e. FOSS, LESP)**
  - **Use MDAO and flight measurements to improve aeroservoelastic modeling and analysis**
  - **Demonstrate ability to derive onboard, in real time, shape and load information**
  - **Develop future research experiments (i.e. distributed conformal trailing edge flap control)**

Update on Aeroelastic Control & Shape Optimization Research

Generic Aluminum Wing Geometry (2 spar, 33 rib, 4 control surfaces)



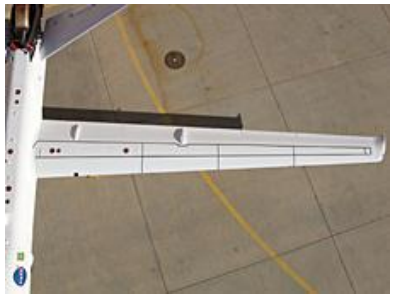
Desktop Testing Environment

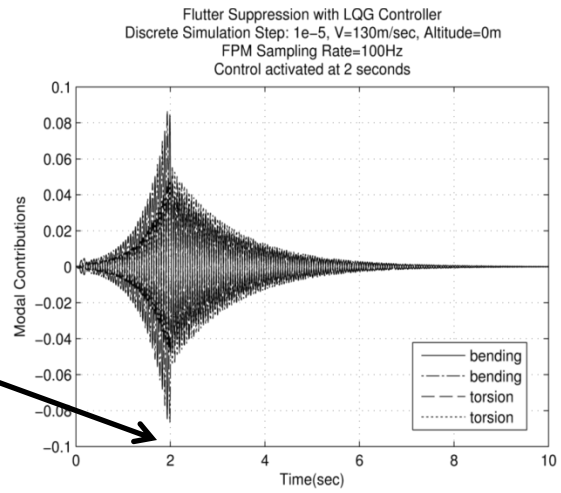


Simulated FOSS

- **Flexible aircraft control with Fiber Optic Strain Sensing (FOSS)**
- **Fictitious Paneling Method (FPM)**
  - **Mapping FOSS algorithmically defined deflections to modal nodes**
    - **Robust shape function mapping (fictitious panels)**
  - **Real-time robust regression of modal coordinates for control feedback**

FOSS on Ikhana



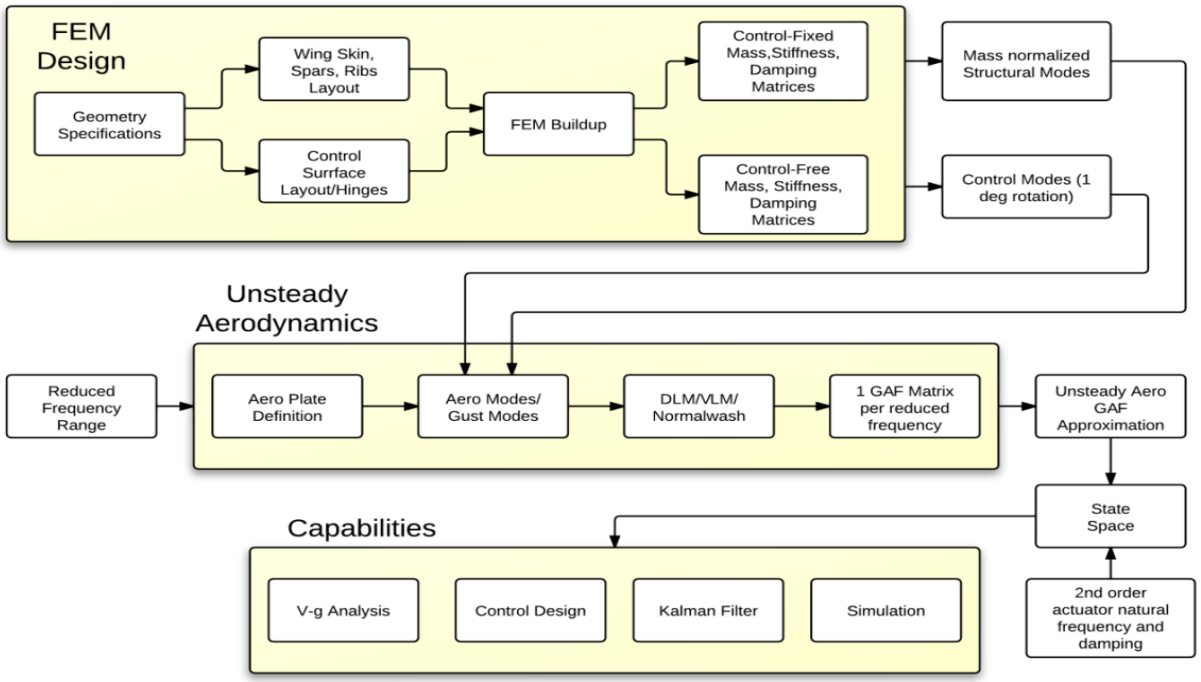


Turn on Suppression System at 2 seconds

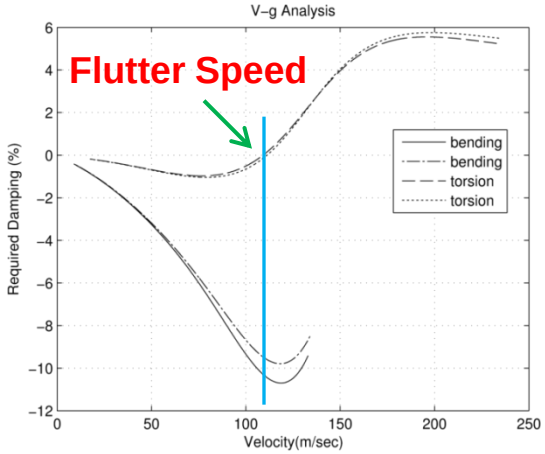
Aeroelastic Research Tool Development

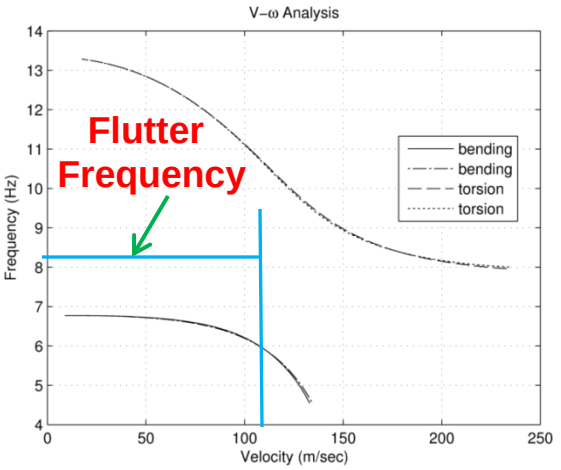
- **Simulation environment based on validated development efforts**
  - **Early course corrections**
  - **Easy to test FOSS in user-defined environment**
  - **Understanding aeroelastic phenomena**

Research Question Tool: Functional Architecture



Analysis Capabilities





Fuel savings through optimization

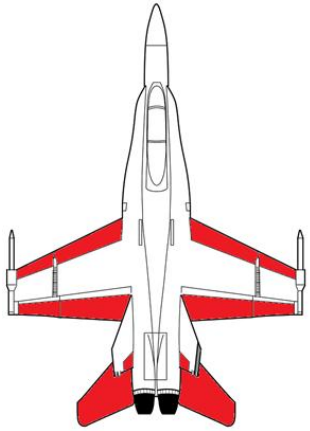
- Intelligent Control for Performance
- Formation Flight

Intelligent Control for Performance

- **Reduce fuel burn with peak-seeking control.**
- **In-flight trim optimization of multiple effectors.**
- **Estimate performance function gradient with a time-varying Kalman filter.**

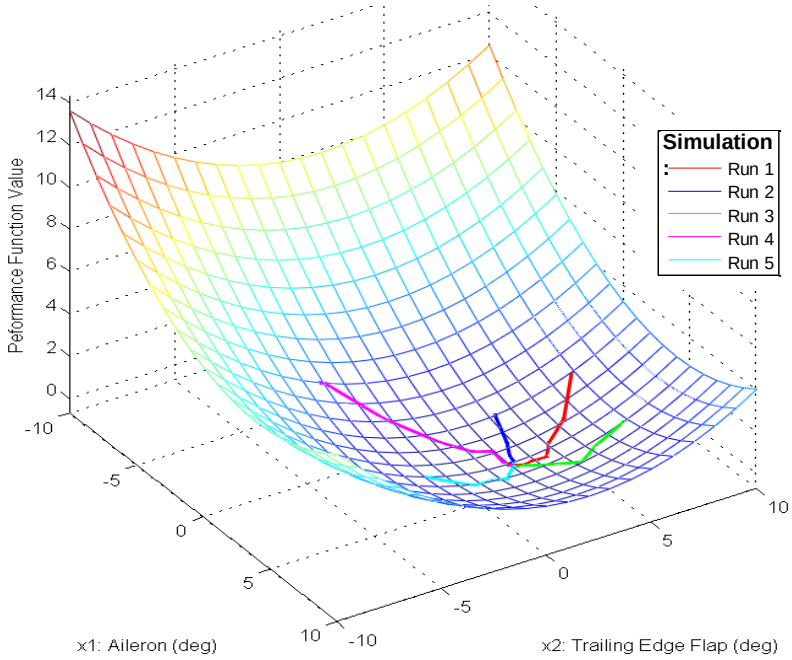
Flight Research Plans

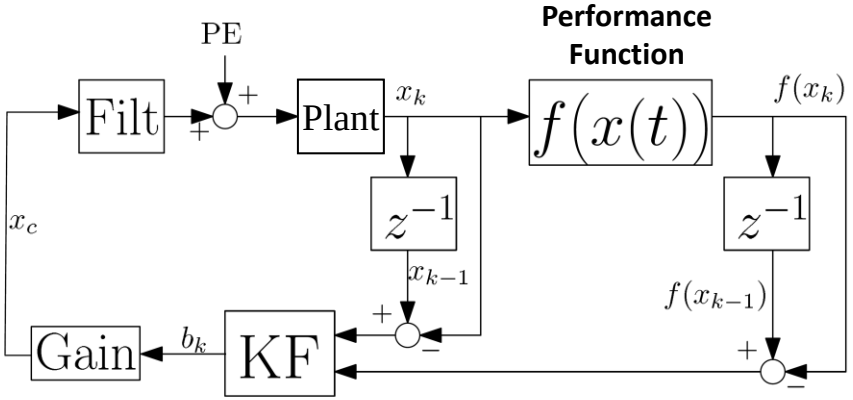
- **Install research-grade fuel flow meters**
- **April: Flight to characterize the performance function**
- **May: Closed-loop ICP research flights**



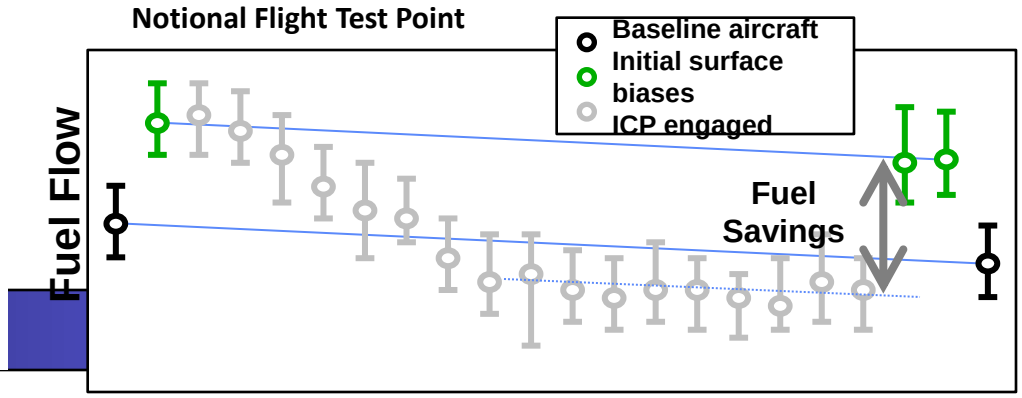
Full-scale Advanced Systems Testbed (FAST) Modified F-18

Performance Function Surface





time-varying Kalman filter



Formation Flight - Potential Development Path

- Address safety concerns and technical risks early
- Integrate with future airspace concept developments
- Leverage partnerships

Commercial Passenger

Commercial Cargo

Military Transports

Increased Economic and Environmental Benefit

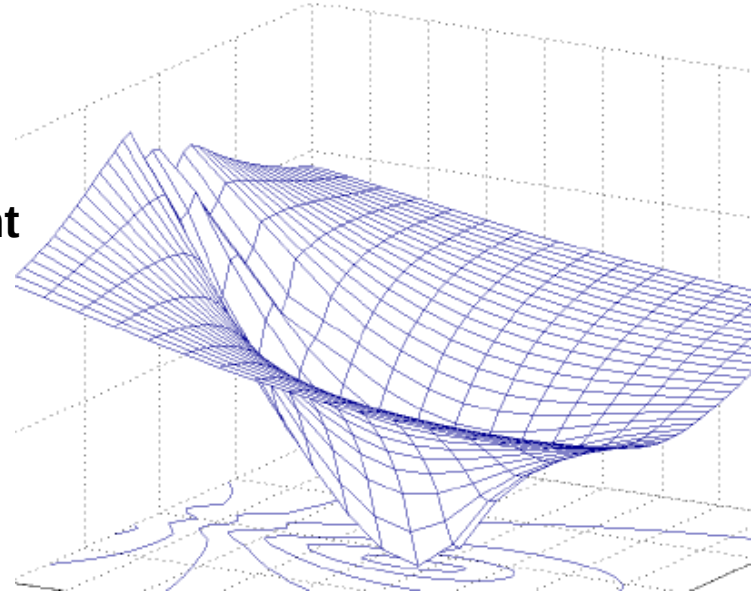
Vortex Sensor Study

Formation flight for drag reduction requires some measure of the vortex position. There are no published studies investigating the optimal sensor or sensor suite to be used for formation flight for drag reduction

I. **Long range coarse sensor to find rough area of vortex**
II. **Short range accurate sensor to find maximum fuel-flow savings**

Identify/develop sensors to meet these requirements

- **The unknown sensor or sensors must be light weight, inexpensive, and possess adequate accuracy.**
- **The ultimate solution may be a collection of disparate sensors whose outputs are combined through an optimal sensor fusion technique.**



Status on other work

F-18 FAST

2012 work

- **Expand the Class B software envelope from 350 KCAS to 300+ knots and lower elevations**
  - **Allows for approach and landing experiments without touchdown**
  - **In flight simulator training**
- **Integrating Leading Edge Stagnation Point Sensor (Tau Systems) for performance evaluation as a feedback sensor**
- **Intelligent Control for Performance Research**

FAST Aircraft to be used for Approach and Landing Test Support for the Dream Chaser Commercial Crew

6°

23°

~30kft AGL

North Edwards

Boron

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Customer Need (SNC)

A high fidelity, low risk, low cost flight environment to:

1. Evaluate the predicted handling qualities of the Dream Chaser vehicle
2. Provide pilot training prior to initial piloted glide and rocket born flights of the actual vehicle

Dryden Approach

Utilize an F/A-18 as an in-flight simulation of the Sierra Nevada Corporation's Dream Chaser, modeling both the rigid body dynamics and the energy properties for piloted approach and landing tests (glide phase)

- DARPA/TTO Demonstration Program
- Demo Autonomous Aerial Refueling (AAR) of one Global Hawk UAV by another
  - First high altitude refueling (up to 45kft)
  - First UAV-UAV refueling
  - First HALE formation flight
  - First precision power control of high altitude aircraft
- Hose/drogue "buddy store" system on receiver, probe to be installed on tanker
- Additional research systems:
  - Airborne Research Test System (ARTS)
  - Sierra Nevada Corporation AAR System
    - Differential GPS
    - Optical Tracking System

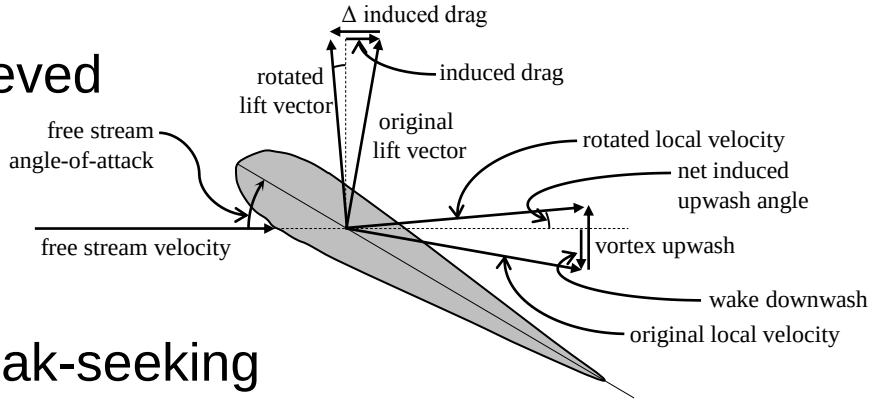
- Tanker first flight, January 2012
- Receiver first flight, February 2012
- Two-ship flight testing starting March 2012
- First Plug in Spring/Summer 2012

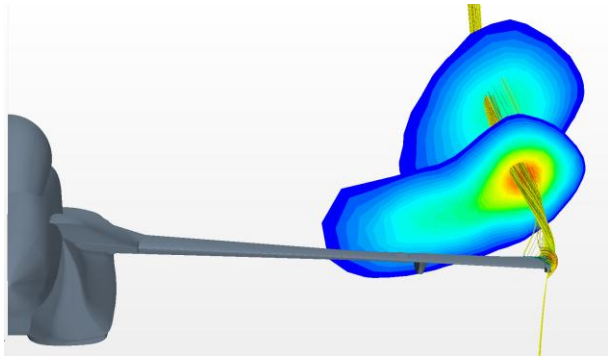
To Fly What Others Imagine …

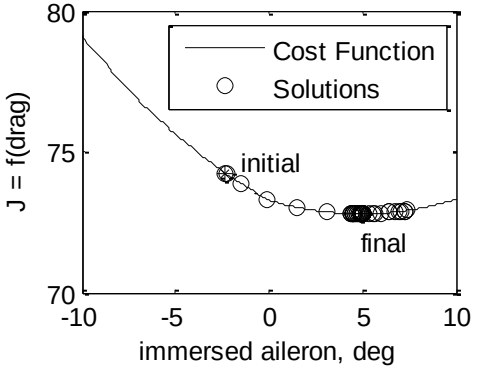
Backup charts

Optimized Lift for Autonomous Formation Flight (OLAFF)

- Experimental in-flight evaluations have shown that the concept of formation flight can reduce fuel use by 10-15%
- Additional drag reduction can be achieved by increasing wing loading near the wingtip immersed in the vortex (Iglesias, 2000 and Hanson, 2009)
- The objective of OLAFF is to apply peak-seeking control technology to the real-time adjustment of the aileron and flap of the immersed wing for optimal drag
- Low TRL activity that could eventually lead to validation through flight research





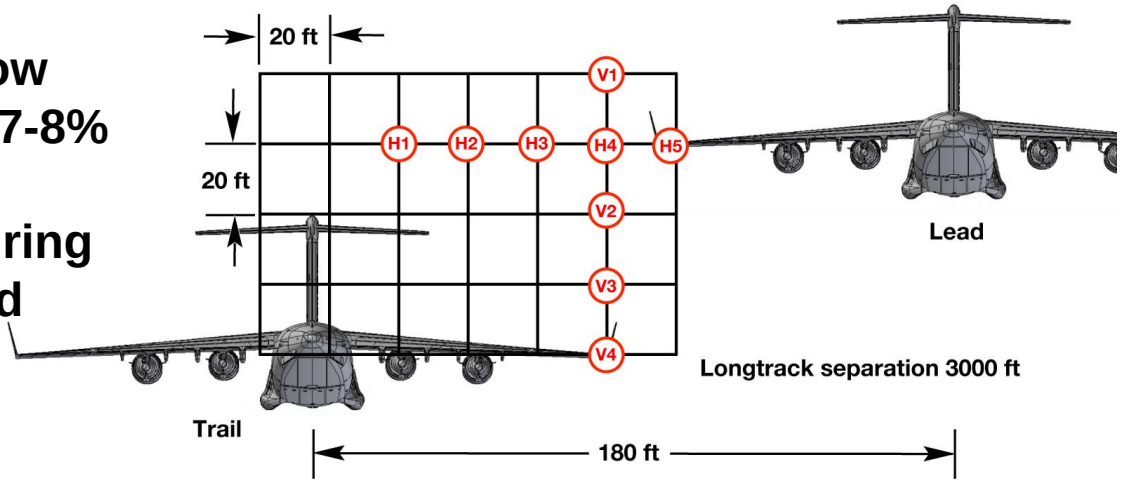


Cargo Aircraft Precision Formations for Increased Range and Endurance (CAPFIRE)

- Utilize existing C-17 FFS, auto-flight system, and instrumentation
- Collect preliminary, qualitative results at various (not optimized) locations near the estimated position of lead's wingtip vortex

- Qualitative flight data and comments were gathered during several two-ship, C-17 formation flights at a single flight condition (275 knots, 25,000 ft)

- The maximum *average* fuel flow reduction was approximately 7-8% (compared to the tare points before and after). This was during test points on both the left and right side



Formation Geometry for Flight Test